IJCAT - International Journal of Computing and Technology
Volume 1, Issue 1, February 2014
www.IJCAT.org

Modification of Ag Thick Film Microstripline Due to Superstrate Strontium Barium Niobate Thick-Films

[1] **S.N. Mathad,** [2] **R.N. Jadhav,** [3] **Pragati.Jadhav,** [4] **Vijaya Puri**

[1] K.L.E. Institute of Technology, Hubli, India.

[2, 3, 4] Thick and Thin Film Device Lab
Department of Physics, Shivaji University
Kolhapur. India. 416004

Abstract - This paper analyzes the properties of environment friendly lead free ferroelectrics at microwave (MW) frequencies. Strontium barium niobates ceramics [$Sr_xBa_{1-x}Nb_2O_6$ (0.40 ≤x ≥0.75)] has been synthesized by simple solid state reaction. Thick films of these ceramics are prepared by low cost screen printing technique. Modification in microstripline properties like microwave transmittance, absorbance and effective dielectric constant are done by simple superstrate (overlay method) strontium barium niobate ceramics in X and Ku band .

***Keywords* - Dielectrics, Ferroelectrics, Thick-film, Microstripline, Superstrate method.**

1. Introduction

Ferroelectric material is a category of material with reorientable spontaneous polarization, a sub-category of pyroelectric materials. Ferroelectric materials have a wide range of applications infrared detectors for security systems and navigation, high density capacitors, high-density DRAMs, non-volatile ferroelectric memory, and high frequency devices such as varactors, frequency multipliers, delay lines, filters, oscillators, resonators and tunable phase shifters etc because of their high dielectric constant (ε ') and high breakdown voltage [1].In theory, all forms of ferroelectric materials, bulk single crystals, bulk ceramics, thin films, and thick-films can be used in RF and microwave tunable applications. Since PZT most common ferroelectric material which is worldwide used. Due to the toxic nature of lead oxide (PbO) many studies on lead-free materials are being conducted. Perovskite oxides such as alkaline niobates (like $KNbO_3$, $LiNbO_3$, $NaNbO_3$,etc) crystal possess many interesting properties including piezoelectricity, pyro-electricity, electro-optic and nonlinear optical response [2].

Strontium barium niobate, $Sr_xBa_{1-x}Nb_2O_6$ (SBN), crystals are attractive for pyroelectric, piezoelectric, electrooptic and non-linear properties. SBN has a strong potential for application in optical data storage, switching and optical computing [3-4]. The main reason for SBN is found most important due to environmental concerns safety and health view point, that lead free materials are being considered for many applications as mentioned above [5].The microwave studies of materials can classified in to non-resonant methods and resonant methods[6].The usual method of examining the microwave properties of overlaid materials is using patterning simple devices like straight resonator, ring resonator are resonant methods, however simple microstripline a non resonant technique [7].

In this study, preparation of $Sr_xBa_{1-x}Nb_2O_6$ (0.40≤x ≥0.75) thick-films through the low cost screen printing process using SBN powder synthesized by solid state reaction. The simplest miniaturized microstrip structure is microstripline (non resonant method) used in measuring, the response and evaluating its properties lead free ferroelectrics at microwave frequencies. Modification in microstripline properties like microwave transmittance, absorbance and effective dielectric constant are done by simple superstrate (overlay method) strontium barium niobate thick-films in X and Ku band. To the authors knowledge there are no reports on the microwave properties of SBN thick films through superstrare (overlay) technique.

2. Materials and methods

Strontium barium niobate ceramics were prepared by simple solid state reaction. For this, the following reactants of analytical grade were used: $SrCO_3$ (99.95%), $BaCO_3$ (99.95%) and Nb_2O_5 (99.999%) were used as starting materials. Powder was crushed for homogenization using agate mortar in acetone medium for 1 hour to get the fine powder. This powder was again mixed in stoichiometric proportion and ground for 4 hours in acetone medium to obtain desired stoichiometry in the resultant compounds.

This mixture was initially sintered at 1200 °C for 10 hrs and further at 850^0C for 48 hours in a muffle furnace. The $Sr_xBa_{1-x}Nb_2O_6$ (0.40≤ x ≥0.75) where x=0.40, 0.5, 0.61 and 0.75 sample was prepared by a low cost, conventional solid state synthesis technique [5,8].The SBN thick-films has been prepared by screen printing due to low production cost. The main objective of this work was to use the superstrate (overlay method) technique on the simple miniaturized Ag thick film microstripline which is a non resonant component to predict the permittivity. The SBN thick-films were kept as in touch overlay (superstrate) at the centre of the microstripline and change in the transmittance and reflectance at strontium contents variations. The investigations are conducted in the very high microwave frequencies 8-18 GHz (in X and Ku-Band) in the absence of external dc magnetic field. To the authors knowledge using Ag thick film microstripline the dielectric studies of SBN thick-films has been reported for the first time.

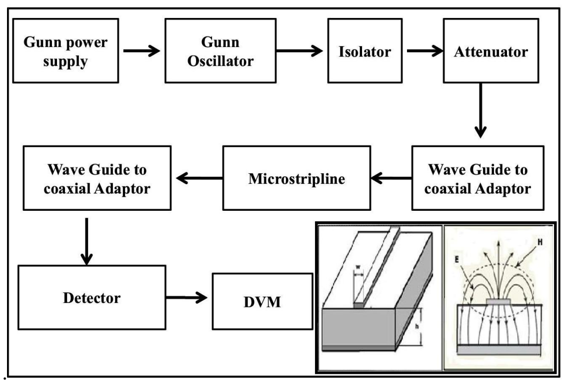

Fig.1.Schematic of experimental setup used for Ag thick film microstripline superstrate study

The Ag thick film microstripline (figure1) was delineated by screen printing silver on 96% alumina (Kyocera, Japan) substrate and fired at 700^0C by conventional thick film firing cycle. The width of thick film microstripline was 0.635 mm for, its transmittance and absorbance as a function of frequency over the X-band (8-12GHz) and Ku-band (13-18GHz).

The microwave transmittance (S_{21}) and reflectance (S_{11}) measurements were made point by point at the microwave frequencies (X and Ku band) with the help of microwave bench consisting of Gunn source, isolator, attenuator, directional coupler and detector shown in Fig.1. In this technique, the change in transmission and reflection of the microstripline with a $Sr_xBa_{1-x}Nb_2O_6$ (0.40≤x ≥0.75) thick-films with different strontium contents kept at the centre the microstripline were measured. Care was taken so that the overlay does not touch the contacts at ends.

The simple miniaturized microstripline is a non-resonant component. When any material is kept on top of the microstrip component (microstripline) it is termed as superstrate (overlay). The transmittance of microstripline with and without superstrate was measured. The transmittance of Ag thick film microstripline without superstrate was subtracted from the transmittance of microstripline obtained with SBN thick-films in order to study the effect of superstrate on the transmittance of the microstripline. Therefore, the graphs are plotted as a change in transmittance versus frequency is shown in Fig.2. It is observed from Fig.2. that transmittance of microstripline decreased due to SBN thick films superstrate in the 8.9-10.5GHz frequency range. Composition dependent behaviour is also observed in Ku band region, but not in systematic manner. Transmittances of Sr50 and Sr61 are more prominent in frequency range of 13.3GHz-15.4GHz, a peak is observed at 14.1GHz and 14.3GHz. Transmittance of Sr40 is least in both X and Ku band below 0.29. The magnitude of change in transmittance is found to be composition dependent.

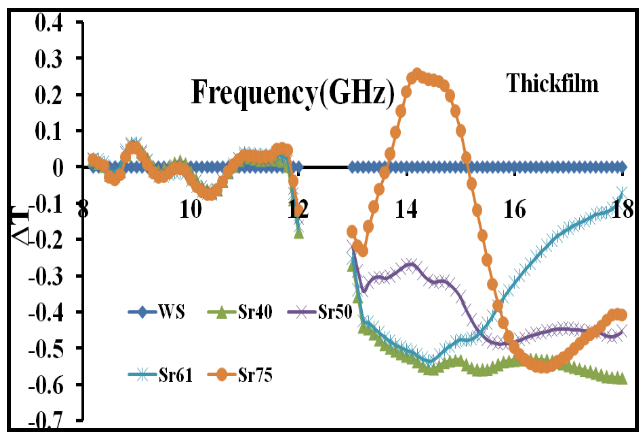

Fig.2 .Change in transmittance of microstripline due to SBN thick film overlay in X and Ku bands

The change in reflectance of microstripline due to SBN superstrate is shown in Fig.3 thick film respectively. Nature of change in reflectance is almost same in X and Ku band. Composition depended feature is absent in thick films. However it is observed for thick films in X band with reflectance of microstripline decreases from 0.60 to 0.17 at higher frequencies at X band in the 10.2 GHz to 12 GHz range for all strontium content. In the case of Ku band significant composition depended variations are observed in microstripline reflectance. The reflectance of the microstripline decreases with increase in strontium concentration (40≤x≥75), in Ku band. The behaviour of reflectance of the microstripline due to thickfilm overlay is almost similar. The microstriplines transmit the electromagnetic waves launched at one end of the microstripline to the other end by the propagating fringing fields. The fringing fields are present on the surface of microstripline. The attenuation is increased, due to decrease in transmittance of microstripline. When a material with dielectric constant higher than air is kept in touch over the microstripline, the fringing fields of the microstripline gets perturbed due to overlay due to increase in effective permittivity (ε_{eff}) which results in the enhancement of width of microstripline experienced by the microwaves i.e. pseudo width[9].This perturbation also causes change in its electrical parameters such as transmission, reflection, resonance frequency (f_r) and bandwidth (Q) value of the component.

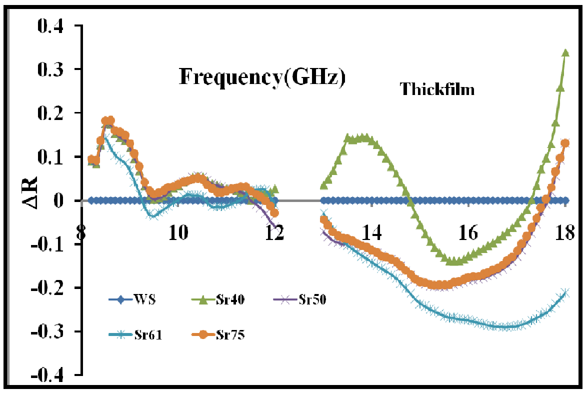

Fig.3. Change in reflectance of microstripline due to SBN thick film overlay in X and Ku bands.

Fig.4. shows the composition dependent, change in microstripline absorbance of with superstrate of strontium barium niobates thick film overlay. The microwave absorption of a material is also dependent upon microstructure, density and porosity of the material [10].As density increases, more and more grain boundaries are available for the reflection of incident microwaves; which results in the increase in return loss and decrease in absorbance of the microwaves.

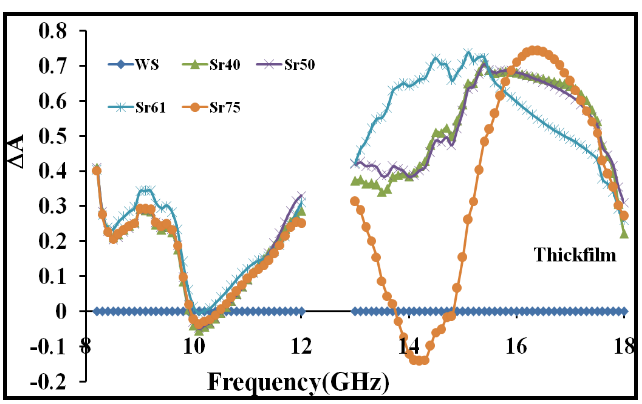

Fig.4. Change in absorbance of microstripline due to SBN thick film overlay in X and Ku bands.

The higher degree of effective impedance matching to the effective impedance of system was obtained and therefore higher absorption in X band than in Ku band. When a material with a dielectric constant higher than air is kept in touch over the microstripline, the fringing fields of the microstripline get perturbed due to overlay due to increase in effective capacitance or permittivity which results in the enhancement of width of microstripline experienced by the microwaves (pseudo width). The overlay also changes the modes (even and odd) of propagation of the microstripline. When an overlay is used the fringing fields gets perturbed, which results in modification of transmission (S_{21}) and reflection (S_{11}).

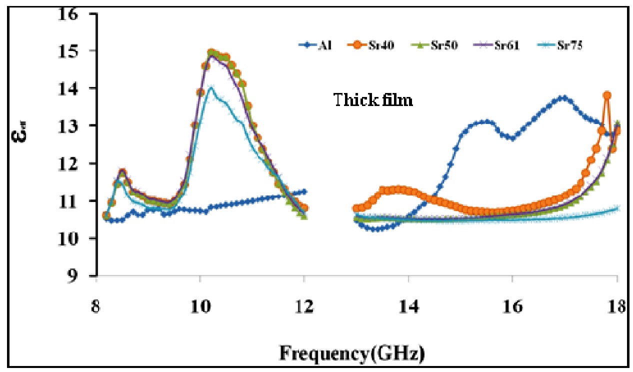

Fig.5. Change in absorbance of microstripline due to SBN thick film overlay in X and Ku bands.

For a microwave engineer the main attraction of ferroelectric materials is the strong dependence of their dielectric permittivity. The dielectric loss in ferroelectrics is not as small as that of common microwave dielectric materials and the loss tangent (tanδ) is an important characteristic of the material, which should be taken into account in the device design. The effective dielectric constants of the SBN overlaid microstripline are shown in Fig.5. The effective dielectric constant with overlay lies in the range of 10.62 to 14.98 due to SBN thick films. Due to the overlay of SBN increase in the ε_{eff} was observed in X band as compared to that in the Ku band. The effective dielectric constant decreases in the Ku band, the decrease being larger due to the thick film. In the X band due to thick film overlay the effective dielectric constant increases with a peak at ~10.3GHz.Whereas due to the bulk overlay slight increase has been obtained. Due to Sr61 and Sr75 overlay the effective dielectric constant shows dispersive behaviour. When the microstrip component is covered by a dielectric material as superstrate or overlay, the fringing field of the microstrip components interacts with the dielectric, which results in the increased effective dielectric constant of the system, which in turn results in the changes in the characteristics of microstrip component. The impedance (Z), phase velocity (v_p) and losses change with the dielectric constant, loss tangent (tanδ) and thickness of the superstrate material. The microwave dielectric constant of superstrate material depends on their shape and size of the grains [11]. As grain to grain contact increases in ceramic becomes more compact which increases the density of sample which results in increasing the effective dielectric constant of microstripline.

3. Conclusions

Strontium substituted barium niobate ferroelectric ceramic were synthesized in a low cost solid state technique. A non resonant cost effective miniaturized microwave component can be used for measuring dielectric constant of SBN thick films. The perturbation causes changes in electrical parameters which are governed by the dielectric constant and size of overlay .Microstripline studies shows composition dependent behaviour is virtually absent in X band, whereas its dominancy observed in Ku band region. Absorbance is larger in the Ku band. The thick-film overlay decreases the ε_{eff} in Ku band and increases in X band.

Acknowledgments

The author V. P gratefully acknowledges UGC, India for the Award of Research Scientist “C”. S.N.M is very much thankful to the management and Principal of K.L.E. Institute of Technology, and R. N. J thanks DST for Award of Women Scientist-A. All the authors also thank DST-PURSE, UGC-SAP.

References

[1] Stanis Courreges, Zhiyong Zhao, Kwang Choi, Andrew Hunt and John Papapolymerou (2010). “Electronically Tunable Ferroelectric Devices for Microwave Applications, Microwave and Millimeter Wave Technologies from Photonic Bandgap Devices to Antenna and Applications”, Igor Minin (Ed.), ISBN: 978-953-7619-66-4.

[2] Rachel Grange, Fabrizia Dutto and Aleksandra Radenovic (2011). “Niobates Nanowires: Synthesis, Characterization and Applications, Nanowires - Implementations and Applications”, ISBN: 978-953-307-318-7, InTech, DOI: 10.5772/19659.

[3] H. Liu, S.T. Li, F.E. Fernandez, G.K. Liu, Thin Solid Films 424, 61 (2003) .

[4] T. Volk, D. Isakov, V. Salobutin, L. Ivleva, P. Lykov, V. Ramzaev, M. Wöhlecke, Solid State Commun.130, 223 (2004).

[5] S.N.Mathad, R. N. Jadhav ,R.P.Pawar , and Vijaya Puri “Electromagnetic Behavior of Lead Free Ferroelectrics at Microwave Frequencies” Advanced Science Engineering and Medicine, Vol. 5, (2013) pp. 1–7.

[6] L.F.Chen, C.K.Ong, C.P.Neo, V. V. Varadan and V. K. Varadan, “Microwave Electronics Measurement and Materials Characterization”, John Wiley & Sons Ltd,(2004).

[7] R. S. Pawar,S. N. Mathad, N. D. Patil, Vijaya R. Puri, “Modification of Ag Thick Film Microstripline Due to Superstrate Ni-Cu-Fe-Mn-O ceramics”, International Journal of Engineering and Innovative Technology, 3, 4 (2013).

[8] S. N. Mathad, Vijaya Puri “Structural and dielectric properties of $Sr_xBa_{1-x}Nb_2O_6$ ferroelectric ceramics” Archives of Physics Research, Vol.3, No. 2 (2012), pp. 106-115.

[9] S. M. Iyer, R. N. Karekar, “Resonance frequency behavior of microstrip resonators for thin film overlays” Electronic Letters, Vol. 28, pp 873, (1992).

[10] R.N.Jadhav, Vijaya Puri, Micro. Inter., 28,53 (2011).

[11] R. N. Jadhav, Vijaya Puri, “Response of Ag thick film microstrip straight resonator to perturbation of bulk and thick film $Ni_{(1-x)}Cu_xMn_2O_4(0 \leq x \leq 1)$ ceramics”, Microelectronics International, Vol. 28, pp. 53, (2011).

.

S. N. Mathad gained his MSc from the Department of Physics, Karnataka University, Dharwad, India. At present he is a Assistant professor in the Department of Physics in a K.L.E.I.T Hubli and also doing a PhD in Shivaji University, Kolhapur. His research area of interest is in miniaturized microstrip components using ferroelectrics and ferromagnetic thick films.

Vijaya R. Puri is a UGC research scientist “C” in the Department of Physics, Shivaji University, Kolhapur, India. She is engaged in research of thick and thin film microstrip components with special emphasis on metallization aspects and overlay technique. She is also working on bio materials, thermistors, ferrites, conducting polymer composites and carbon nanostructures for use in planar form with microwave components. Dr Vijaya Puri is a member of IEEE (USA), MTT, CHMT, Magnetic and AP-S societies, and life member of IMAPS India.

R. N.Jadhav has done her MSc and PhD in the Department of Physics, Shivaji University, Kolhapur, India. At present DST, India has awarded her Women Scientist-A. The area of her interest is thick film thermistor with high thermistor constant and microwave power sensor in planar form.

Pragati.Jadhav has done his MSc in Department of Physics, Shivaji University. At present he is pursuing PhD. Her area of interest is Material Science for microwave devices.